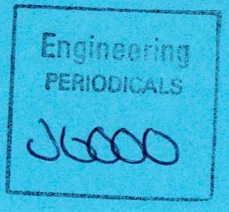

# AN INVESTIGATION OF THE LATCH MECHANISM OF SAFETY DOORS OF A BARREL TILTING MACHINE




**DRAFT**

**REPORT OF**

**Dr Colin Goodchild C. Eng. MIEE**

**September 12, 1995**

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|---|---|---|
| Specialist Field | : | Systems Engineering |
| On behalf of | : | Vesuvius U.K. Limited |
| On the instructions of | : | Paul F. J. Wade of Simpson & Marwick W. S. |
| Subject Matter | : | Investigation of a latch mechanism on the safety doors of a barrel tilting machine. |
| Inspection Dates | : | September 5, 1995 and September 11, 1995 |

Dr. C. Goodchild Senior Lecturer
The Dept of Aerospace Engineering, University of Glasgow
Tel 0141 330 4069 Fax 0141 330 5560

(1.00 Introduction

Report of : C Goodchild

Specialist Field :Systems Engineering

On behalf of :Vesuvius U.K. Ltd

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# REPORT

## 1.00 INTRODUCTION

### 1.01 Formal Details

Name: Colin Goodchild,

Position: Senior Lecturer for the Department of Aerospace Engineering at the University of Glasgow.

Address: James Watt Building, The University of Glasgow, Glasgow, G12 8QQ.

Specialist Field: Systems Engineering.

On behalf of: Vesuvius U.K. Limited, of Brown Street, Newmilns, Ayreshire,

On the instruction of: Paul. F. J. Wade of Simpson and Marwick W.S. Solicitors, 93 West George Street, Glasgow. G2 1PB.

### 1.02 Synopsis

In the case of James Laing in which Mr Laing alleges that while operating a barrel tilting machine, equipment reference number 03-01-12 in the factory of Vesuvius U.K. Ltd, he was injured by a safety door, forming part of the machine, springing open unexpectedly. I am advising the solicitors representing Vesuvius

U.K. Ltd of the possibility of the said safety door operating in an unexpected and hazardous fashion.

**1.03 Instructions**

I am asked to inspect the barrel tilting machine in its present state and express an opinion on a plausible mechanism which would cause the machine to malfunction and result in the tilting apparatus safety doors springing open unexpectedly when the tilting platform returns to its base position from the inverted barrel-emptying process.

**1.04 Disclosure of Interests**

I have no connection with any of the parties, witnesses or advisers involved in this case, except as necessary for the assessment of the tilting machine.

**1.05 Appendix 1**

Appendix 1 contains details of my experience, qualifications appointments and specialist fields.

**1.06 Appendix 2**

Appendix 2 describes the operation of the barrel tilting machine and gives details of the safety features.

### 1.07 Appendix 3

Appendix 3 gives details of the qualitative test I performed on the barrel tilting machine. A quantitative assessment of the forces associated with the opening safety door are also presented.

### 1.08 Appendix 4

Appendix 4 are photographs I took of the barrel tilting machine during the visits I made to its locus. The photographs show the positions of the tilting platform during normal operation and details of the safety door latch mechanism.

## 2.00 BACKGROUND AND THE ISSUES

### 2.01 The Relevant Parties

The names of the following parties are referred to in this report:

The Pursuer: James Laing

The Defenders: Vesuvius U.K. Limited

Solicitors for the Defender: Paul F. J. Wade
Victoria Gordon

Agents of the Defender: Ian Leyden - Health & Safety Officer.
Robert McFadzen - Process Operator.
Robert Gemmel - Maintenance Technician.
David **** - Electrician.

## 3.00 INVESTIGATION OF THE BARREL TILTING MACHINE

### 3.01 Visits to the locus

I attended the locus of the barrel tilting machine, equipment reference number 03-01-12, at the premises of Vesuvius U. K Limited on two occasions. The first visit was at 14:45 hours on Tuesday September 5th 1995. I spent 1.5 hours inspecting the machine and observing its operation. During the inspection I was accompanied by;

Mr Paul F. J. Wade and Ms Victoria Gordon,
Solicitors for Vesuvius U.K. Ltd.
Mr Ian Leyden, Health & Safety Officer employed by Vesuvius U.K Ltd.
Mr Robert McFadzen, Process Operator employed by Vesuvius U.K. Ltd.
Mr Robert Gemmel, Maintenance Technician employed by Vesuvius U.K. Ltd
Mr David ****, Electrician employed by Vesuvius U.K. Ltd.

The second visit to the locus was on Monday 11th of September at 10:00 hours. I spent 30 minutes carrying one further test. During this visit I was accompanied by;

Mr Ian Leyden, Health & Safety Officer employed by Vesuvius U.K Ltd.

**3.02 First visit to the locus**

I observed a materials handling machine with the equipment reference number 03-01-12. The machine is used to transfer graphitized-alumina from metal storage-barrels to another container. The process of transferring the contents of the barrels to the other container was demonstrated by Mr. R. McFadzen. During the demonstration I took the photographs shown in Appendix 4, these photographs show details of the barrel tilting machine and its operation. During the first visit I carried out the qualitative test described in Appendix 3 under the headings 5/9/95-1 and 5/9/95-2.

I paid particular attention to the operation of the safety doors and their locking mechanism. The purpose of the safety doors is to stop the barrels from falling off the tilting platform while the platform is being raised and lowered.

Under normal operation the safety locking mechanism was seen to hold the doors closed and prevent the operation of the tilting platform when the doors were not secured in the closed position.

This inspection demonstrated that it is impossible for the safety doors to spring open while the tilting machine is functioning correctly.

By physically disabling the safety interlock mechanism, the operation of the tilting platform was made possible with the safety doors open. The barrel tilting machine was tested in this condition to see if the unlocked safety doors would spring open. The tilting platform was raised and lowered both with and without barrels on board. These tests were unable to produce the effect of the safety doors springing open. The only observed unaided opening motion was the right hand door opening to a maximum 25 degrees in period of 3 seconds.

Mr R Gemmel explained the maintenance schedule for the machine. The schedule detailed the maintenance and repair record of the barrel tilting machine for the previous twelve months (September 1994 to August 1995).

**3.03 Second visit to the locus**

My second visit to the locus was to conduct further tests on the barrel tilting machine, equipment reference number 03-01-12. During this second visit I carried out the qualitative test detailed in Appendix 3 under the headings 11/9/95-1 and 11/9/95-2. The objective of these tests was to attempt to make the right hand safety door spring open. I carried out a qualitative test to examine

the effect of an barrel being forced against the unlocked safety doors while the tilting platform is in the fully lowered position. For this test I was accompanied by Mr Leyden.

The test produced the effect of the door opening a full 90 degrees The rate at which the door moved was easily stopped by Mr Leyden raising his left hand to intercept the doors swinging towards his position.

I found that it was possible for the right hand door interlock limit switch to operate before the door was manually latched. The barrel tilting machine was operated in this condition. During the lowering operation the right hand safety door opened when the tilting platform returned to its base. However, I did not consider the rate at which the door opened to be unsafe.

## 4.00 FACTS ON WHICH MY OPINION IS BASED

a) To examine the barrel tilting machine in its present condition and assume the absence of the pneumatically operated bolt now fitted to the safety doors.

b) To consider mechanisms that can cause the right hand safety door to spring open when the tilting mechanism is lowered with an empty barrel on the tilting platform.

c) My assessment is based on my observations and verbal enquiries to the Vesuvius personnel who were in attendance while I examined the barrel tilting machine. Design documentation, specifications, drawings and design calculations were not available for my inspection.

## 5.00 CONCLUSION

### 5.01 First Issue

Regarding the issue of a mechanism to cause the right hand safety door of the barrel tilting machine springing open in a spontaneous manor while the tilting platform is returning to its lowered position:

a) I found no mechanism that would cause the door to spring open in an apparently uncontrollable and potentially hazardous fashion.

b) I found that it was possible to operate the tilting platform with the safety doors unlocked. However, operating the tilting platform only produced an easily and safely controlled opening of the doors to a maximum of about 25 degrees. The swinging action of the door is resisted by the hinge friction.

c) By deliberately forcing an empty barrel against the unlocked, right hand safety door I made the door open to 90 degrees at a rate which was easily and safely controlled by human hand force.

Signature_____ Date_____

Name_____

# APPENDICES

## CONTENTS

## A1 EXPERIENCE, QUALIFICATIONS APPOINTMENTS AND SPECIALIST FIELD

### A1.1.1 Experience

I have been an aerospace systems engineer for 19 years. For the last 11 years I have lectured courses in aerospace systems in the Department of Aerospace Engineering at the University of Glasgow. During this employment I was engaged to as a consultant by a major aerospace equipment company investigate system failures in a combat aircraft.

From 1977 to 1984 I was employed as Research Engineer for GEC Marconi Research Laboratories where I was engaged in a variety of investigative projects involving electrical, mechanical, pneumatic and hydraulic problems, mainly associated with military systems.

Before graduating as an electronics engineer I was employed as an electronics technician for 2 years by the University of Essex and before that for 1.5 years by the GEC Marconi Communications Company. In both these employments I was engaged to fault find, repair and calibrate electronic and electromechanical equipments.

My work experience started in 1963 as an apprentice electrician. I completed the apprenticeship and qualified in several branches of electrical installation and repair trades. I am listed on the current

register of U.K electricians and qualify for the European electrical occupations 1,2,3,4,5,6, and 9.

### A1.1.2 Qualifications

I am a Chartered Engineer and Member of the Institution of Electrical Engineers. I have a Ph.D. from the University of Glasgow, a M.Sc. in Aerospace Systems from the Cranfield Institute of Technology and a B.Sc. (Hons) in Electronic Engineering from the University of Essex.

I also hold an HNC in Electrical and Electronic Engineering as well as several C&GLI certificates in electrical, electronic, instrumentation and control. I have qualified as Technician Electrician and hold both the Electricians Certificate and FTC awarded by the C&GLI in association with Electrical Trades Union and Electrical Contractors Association.

### A1.1.3 Appointments

I am a employed in the Department of Aerospace Engineering of the University of Glasgow. My position is a Senior Lecturer in Aerospace Systems.

I have served on the IEE Professional Group PGE15 and I am currently a member of the Avionics Committee of the R.Ae.Soc.

### A1.1.4 Specialist field

My specialist field is systems engineering. This covers electrical and mechanical systems; their design, analysis, control and instrumentation.

## A2 DESCRIPTION OF THE BARREL TILTING MACHINE, ITS OPERATION AND SAFETY FEATURES

### A2.1.1 Site of the barrel tilting machine

The machine, called a barrel tilting machine, is used to lift and discharge the contents of barrels into another receptacle which is placed on the floor below the machine. The barrel tilting machine is located next to a smaller materials handling machine in the corner of a single storey industrial building which serves mainly as a storage area for the barrels. The building is illuminated by artificial lighting. The area around the machine was seen to be well organised and tidy. During my inspection there was adequate access on the three sides of the machine where the operators are required to carry out the barrel discharging process.

### A2.1.2 Overview of the condition of the barrel tilting machines

On the machine there is evidence of maintenance, repairs and modification. Various parts of the machine have repair welds. A significant modification is the addition of a pneumatically actuated bolt that engages when the tilting mechanism is activated. The machine also shows signs of wear damage. In particular I noted the axis of the hinge line of the right hand safety door was not vertical and results in the misalignment of the door. I also observed the arm of the safety interlock limit switch - that is attached to a bracket on the right hand door - had been bent through an angle of about 45 degrees. A pneumatic actuator is mounted on each door, these

actuators push a ram on the side of the barrels loaded onto the tilting platform. There is noticeable polished surface around the airline connection of a pneumatic actuator mounted on the right hand safety door. This appears to be caused operator handling as it is the means by which the safety door is manually opened and closed.

### A2.1.3 Description of the barrels

The barrels have the appearance of the type often referred to as the Forty-five-Gallon Oil-Barrel and are used by Vesuvius U.K. Limited to store graphitized alumina. The barrels are manufactured from metal sheet and have dimensions 0.6 metres diameter and 0.85 metres height.

### A2.2.1 Overview of the barrel tilting machine and its operation

The barrel tilting machine comprises a roller conveyor to transfer the barrels to and from the tilting mechanism, a tilting platform and a barrel discharge shoot. The tilting platform moves through an arc which raises and tilts simultaneously the barrels. The shoot assembly directs the contents issuing from the barrels into a receptacle positioned below the machine. The machine has the capacity to empty two barrels together.

Barrels of graphitized-alumina are raised by a an electrically powered gantry- hoist and transferred to the roller conveyor. One or two barrels are manually pushed along the conveyor onto the tilting platform.

### A2.2.2 Operation of the tilting platform safety doors

The tilting platform is fitted with safety doors which must be closed and bolted before the tilting platform can be operated. To secure the safety doors in the closed position, the operator must first push the left hand door closed and manually engage a door latch. In a similar way, the operator closes and latches the right hand door. The action of closing both doors operates a safety interlock limit switches attached to each door.

### A2.2.3 The tilting platform safety interlocks

The action, enabled by the limit switches, is to permit the application of electrical power to the tilting platform mechanism. The operation of the tilting platform is initiated by pressing the start button on one of two parallel connected motor starter units. The motor starter units are mounted on each side of the machine adjacent to tilting platform.

### A2.2.4 Operation of the tilting platform

The action of the tilting platform raising and tilting the barrels causes the activation of three pneumatic actuators. Two pneumatic actuators are mounted on the safety doors, with one actuator located centrally on each door. The linear stroke of these actuators moves perpendicular to the plane of the safety doors and pushes rams against the barrels on the tilting platform. The third pneumatic actuator is an automatic locking system for the safety doors. This device was fitted as a modification to the barrel tilting machine. All

three pneumatic actuators are powered from the building's high pressure air supply.

With the barrels held on the tilting platform, the assembly is raised above shoot. A shaking action is applied to the inverted barrels to ensure the release of all the graphitized-alumina contents. Using the second hand of a wrist watch to time the platform movements shows it takes approximately 17 seconds to raise the barrels and a further 17 seconds to lower the assembly.

### A2.2.5 Removal of empty barrels from the tilting platform

With the tilting platform returned to the initial position. The safety doors automatic and manually operated latches are released. The operator pulls the safety doors open to allow the manual removal of the barrels from the tilting platform and deposits them on the floor next to the tilting machine. This completes one cycle of the sequence of the process of discharging graphitized-alumina from their storage barrels into another container. I was advised that the time an operator requires to process two barrels is between 5 and 8 minutes.

## A3 DETAILS OF THE INSPECTION AND TESTS PERFORMED ON THE BARREL TILTING MACHINE

### A3.1.1 Focus and objective of the test

The focus of this assessment is the operation of the right hand safety door and its associated closing, locking and opening mechanisms. The objective of the inspection and tests is see if there is a plausible mechanism or sequence of events will cause the door to spring open in a unexpected and hazardous manor. Under normal circumstances with the safety doors open and unlatched operation of the tilting platform is prevented by the electrical switch interlock system described in section A2.2.3. The interlock switch is a lever operated limit-switch mounted on the right hand safety door and operates when the safety door is pulled into the fully closed position by the action of the manually operated latch.

### A3.1.2 Examination of the movement observed of the right hand door

**Test 5/10/95-1**

For this focused assessment I ignored the additional locking feature provided by the pneumatically activated automatic bolt. I was told the pneumatically activated bolt was fitted as a modification after the alleged injury to Mr Laing had occurred. I noted the misaligned right hand hinge caused the door to swing open to about 25 degrees; it took approximately three seconds for the door to swing through this angle and, in my opinion, was not a dangerous movement. Further, the unaided opening could only be initiated after the door was

released from the friction grip of the distorted components of the automatic latch assembly.

I was advised by Mr Gemmel, the maintenance technician, that I could assume a door weight of 40 pounds which I took as 20 kilogrammes-force for the purpose of making quantitative assessments. From these estimates I performed the following calculations to obtain a qualitative but inconclusive assessment of the forces associated with the observed right hand door movement.

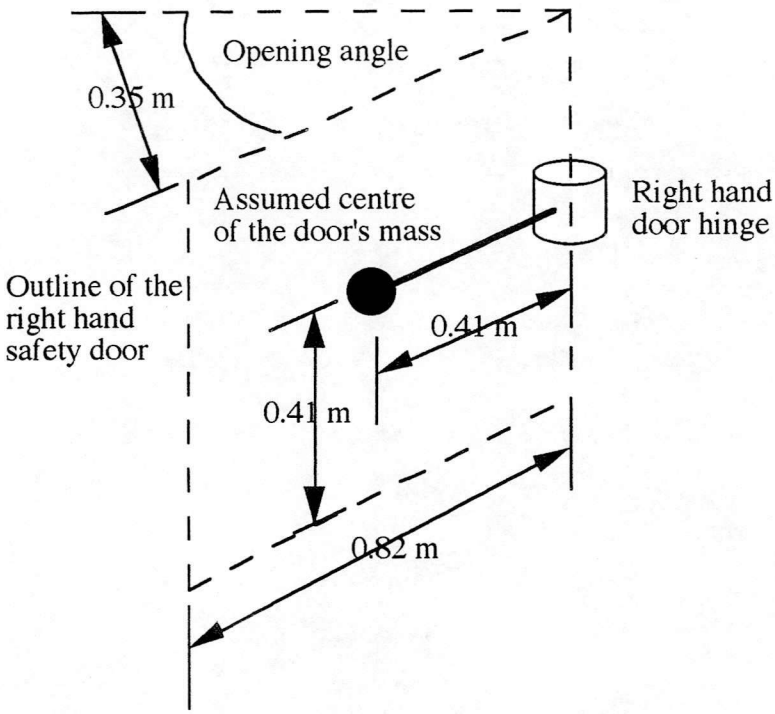
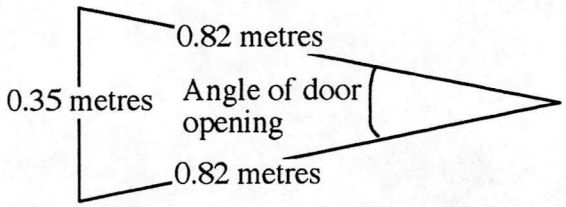



Figure A3.1 The assumed geometry used to quantify the dynamics of the observed unaided opening of the right hand safety door.

The width of the right hand safety door measured 0.82 metres

The gap between the door and door frame measured 0.35 metres

This gives the geometric model:




The angle of door opening derived form this geometry is

24.64 degrees.

The rate at which the door opened was timed to be 3 seconds to open the measured 0.35 metres. This corresponds to 8.21 degrees per second (0.143 rads per sec). This estimate ignores the accelerations and thus assumes an average opening rate.

With the assumed door weight of (20 kgf) 196.12 N, the mass of the door 20 kilogrammes. The centre of this mass is assumed to correspond with the centre of the door. The inertia J of the door assembly is therefore estimated to be

3.362 kilogramme metre-squared

The angular momentum is hence calculated to be

0.481 kilogramme metre-squared per second.

The kinetic engery $E_k$ is calculated to be

0.0344 Joules

**Test 5/10/95-2**

To determine the effect of raising and lowering the tilting mechanism with the safety doors unlocked, the interlock limit switch was deliberately held in a position that allowed tilting mechanism to start with the doors still open. The tilting platform was raised and lowered several times both with and without barrels on the platform. These test did not produce the effect of the right hand door springing open.

**Test 11/10/95-1**

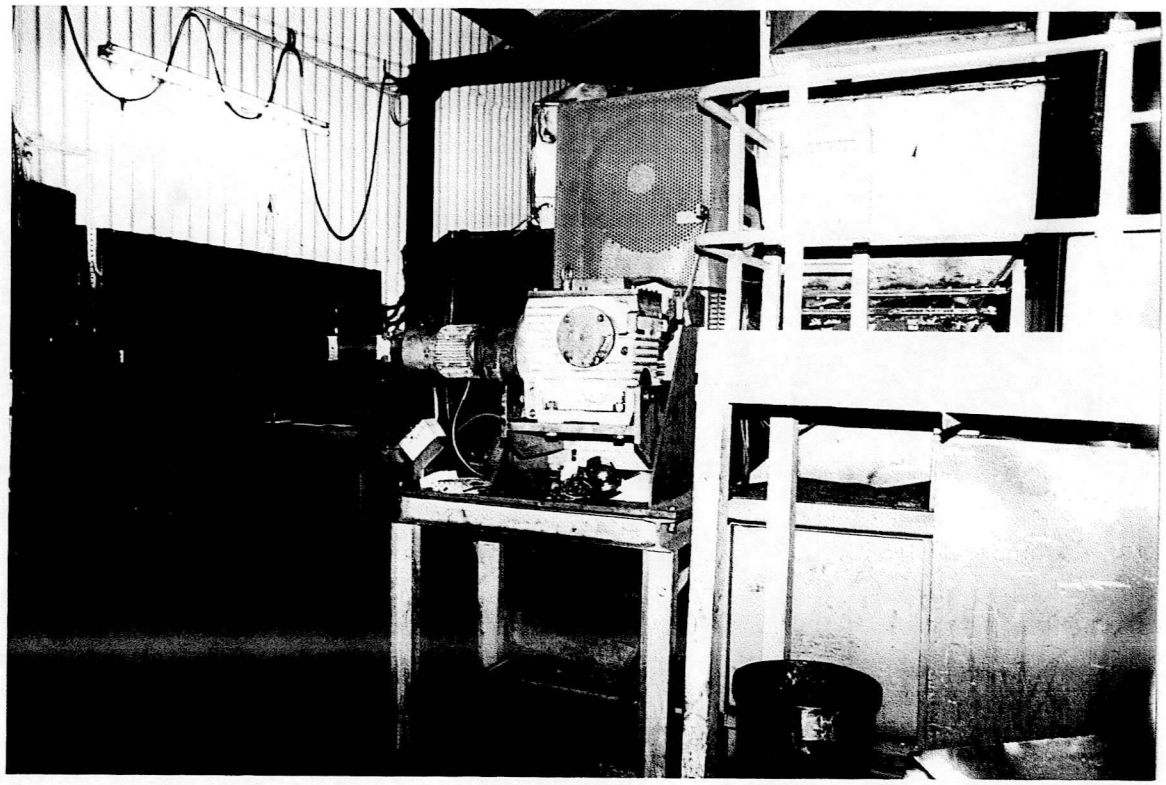
The test I carried out involved loading the right hand side of the tilting platform with an empty barrel. I stood on the left hand side of the tilting platform and Mr Leyden stood in the position of the operator, on the right hand side of the platform. With the safety doors closed but unlocked, I jerked the barrel against the safety door. The safety door swung open by about 90 degrees. The rate of swing was not high and the door was easily stopped by Mr Leyden raising his hand to intercept the advancing assembly.

**Test 11/10/95-2**

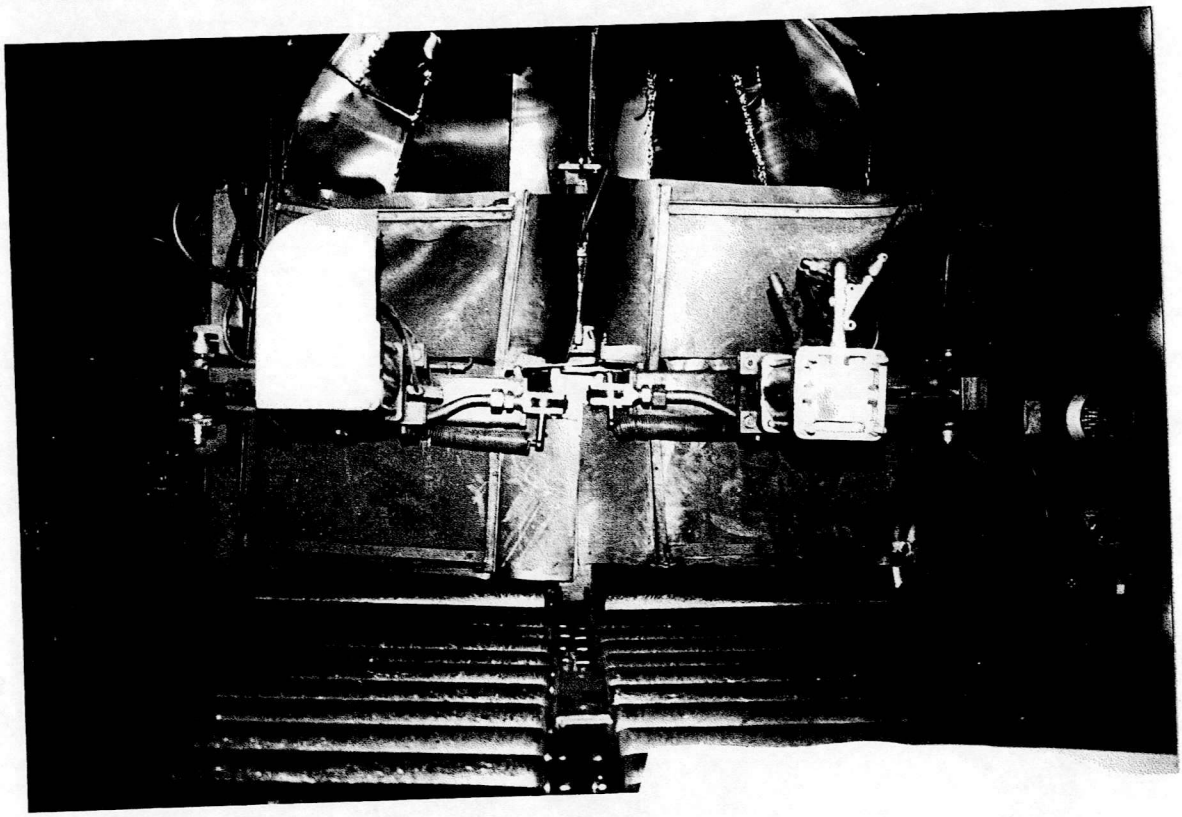
Examination of the right hand interlock limit switch showed that the switch could be activated before the right hand safety door was locked by the manually operated latch. I set the safety doors in this position and observed the tilting platform lowering with an empty barrel. On reaching the base position the right hand safety door drifted open to about 25 degrees.

## A 4 PHOTOGRAPHS OF THE BARREL TILTING MACHINE AND DETAILS OF ITS SAFETY DOOR LATCH

Photograph 5/9/95-A41 General view of the right hand side of the barrel tilting machine. The tilting platform actuator and gearbox are in the centre. The roller conveyor along which the barrels are pushed onto the tilting platform is part of the machine at the left of the picture.

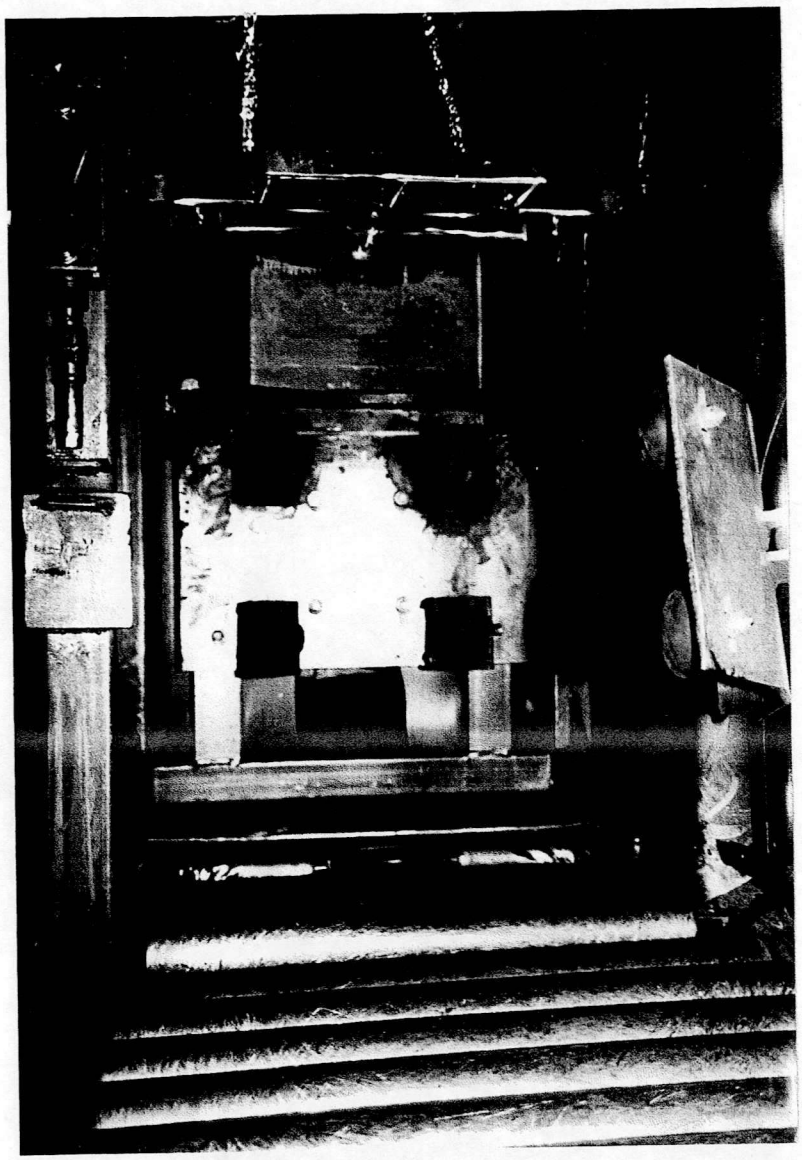


Photograph 5/9/95-A42 The rear of the barrel tilting machine looking along the roller conveyor towards the tilting platform. The safety doors are closed position.

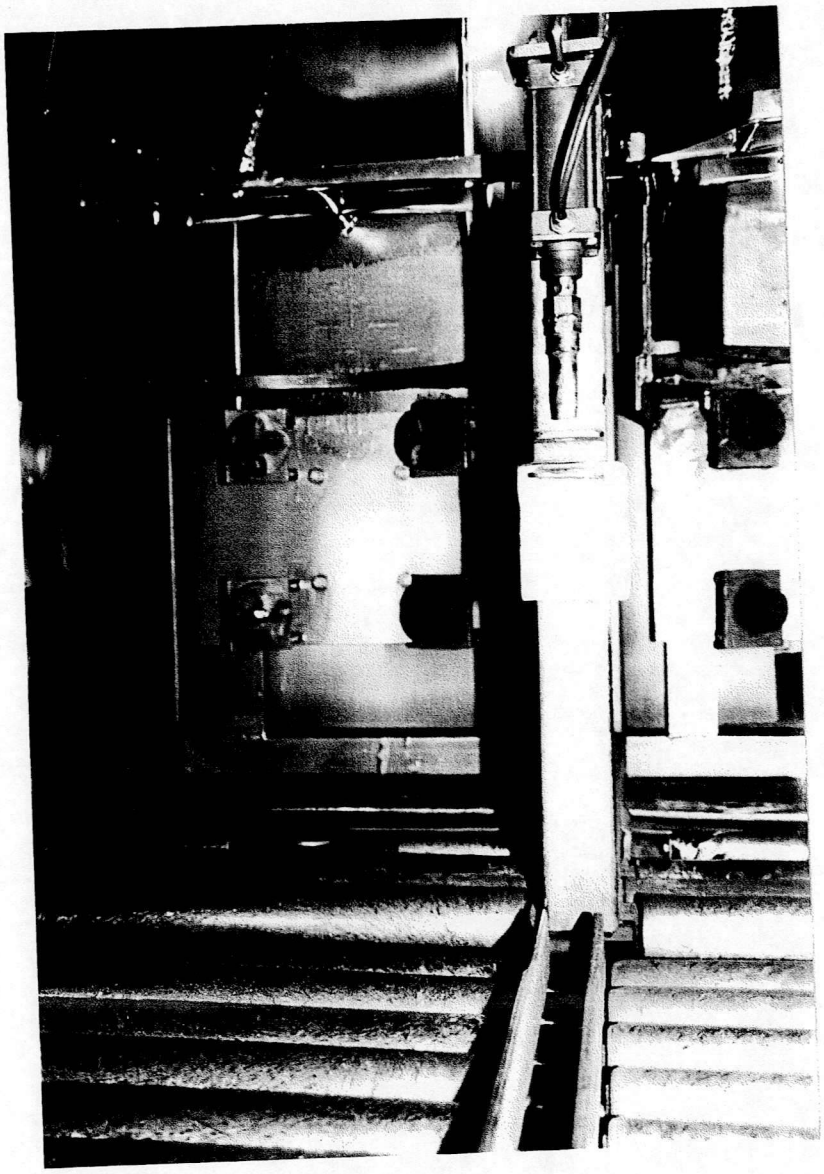


Photographs 5/9/95-A43 and 5/9/95-A44 The next two photographs are views of the right and left hand sides if the tilting platform respectively. The safety doors are open. The pneumatic bolt for to lock the safety doors is seen attached to the column on the left side of 5/9/95-A43.

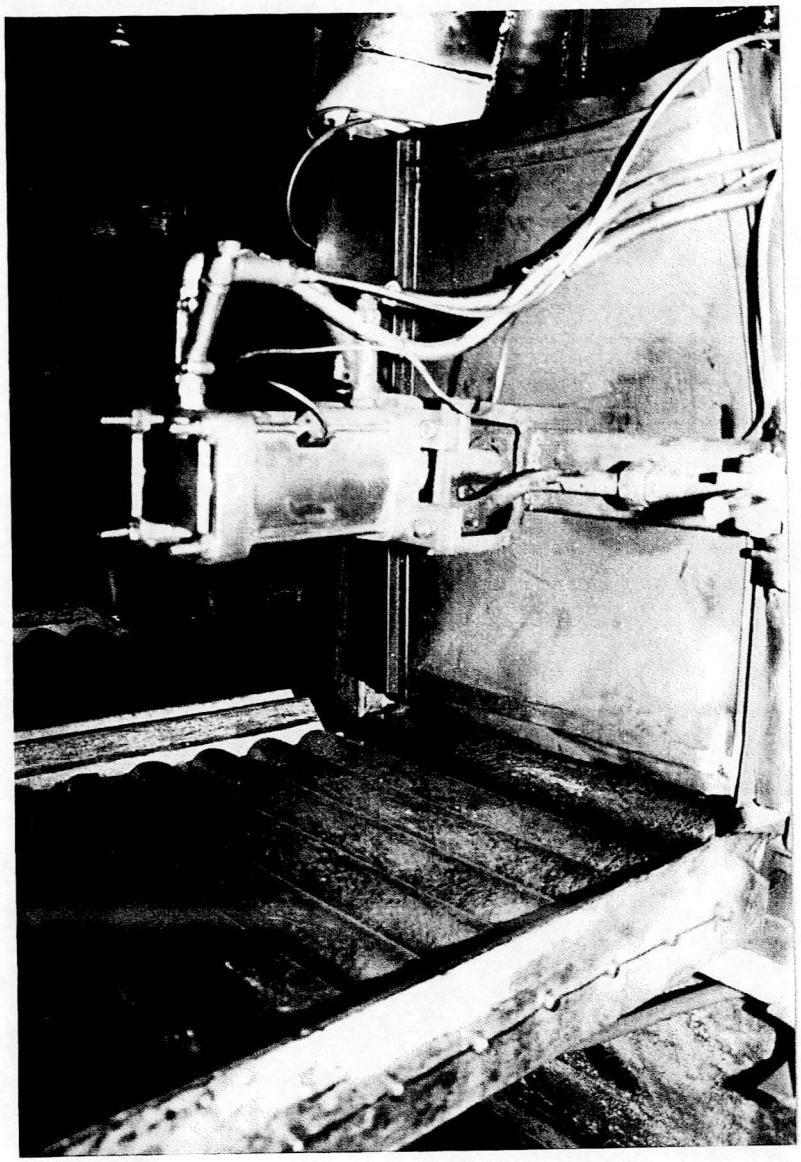
5/9/95-A43



5/9/95-A44

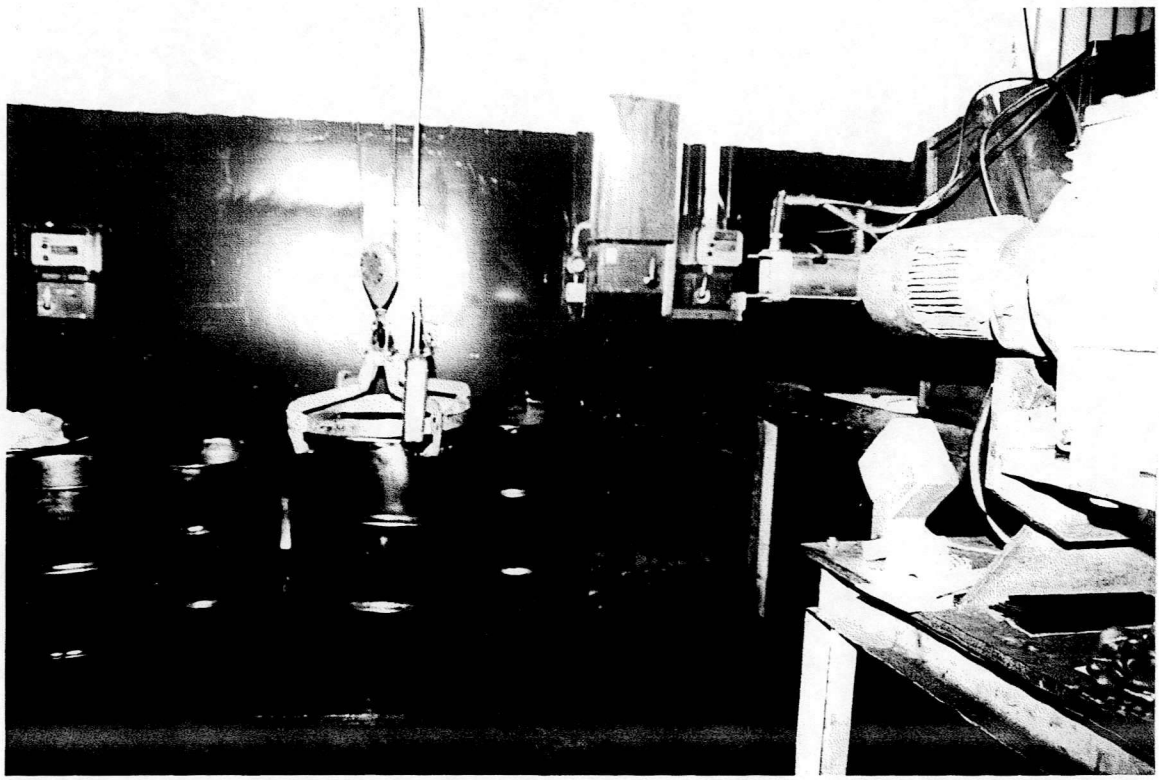


Photograph 5/9/95-A45 The ram pneumatic actuator for clamping the barrels in place on the right hand side of the tilting platform in the centre of the picture. The actuator is attached to the horizontal arm that extends from the right hand safety door hinge.



Photographs 5/9/95-A46, 5/9/95-A47, 5/9/95-A48 and 5/9/95-A49 is a sequence of pictures showing the process of loading a barrel with the overhead gantry hoist and the platform tilting from the base position to the fully raised position were the barrel discharges its contents.

5/9/95-A46



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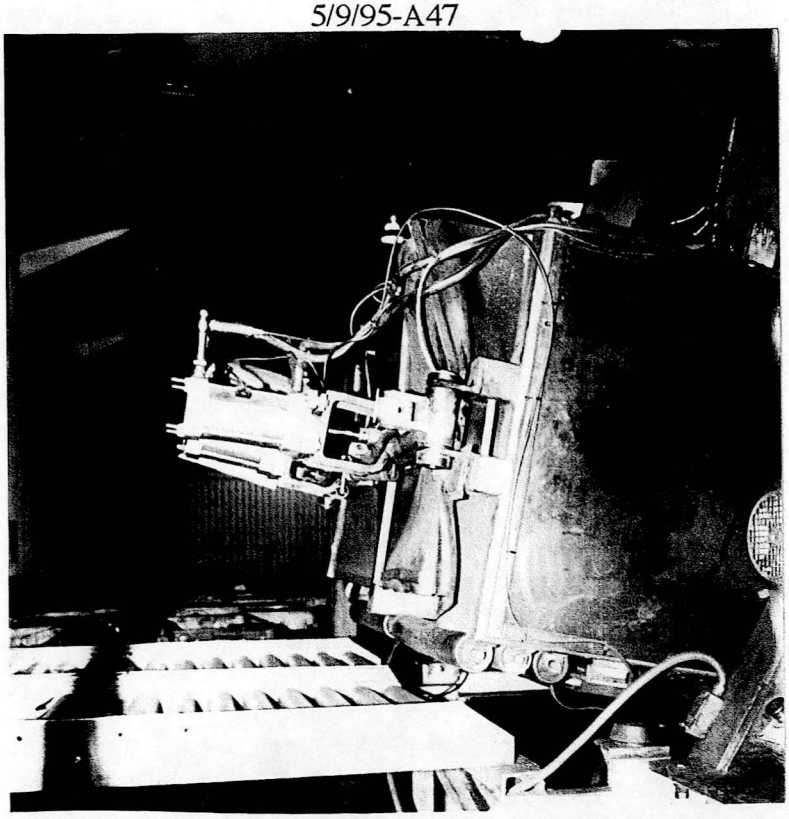
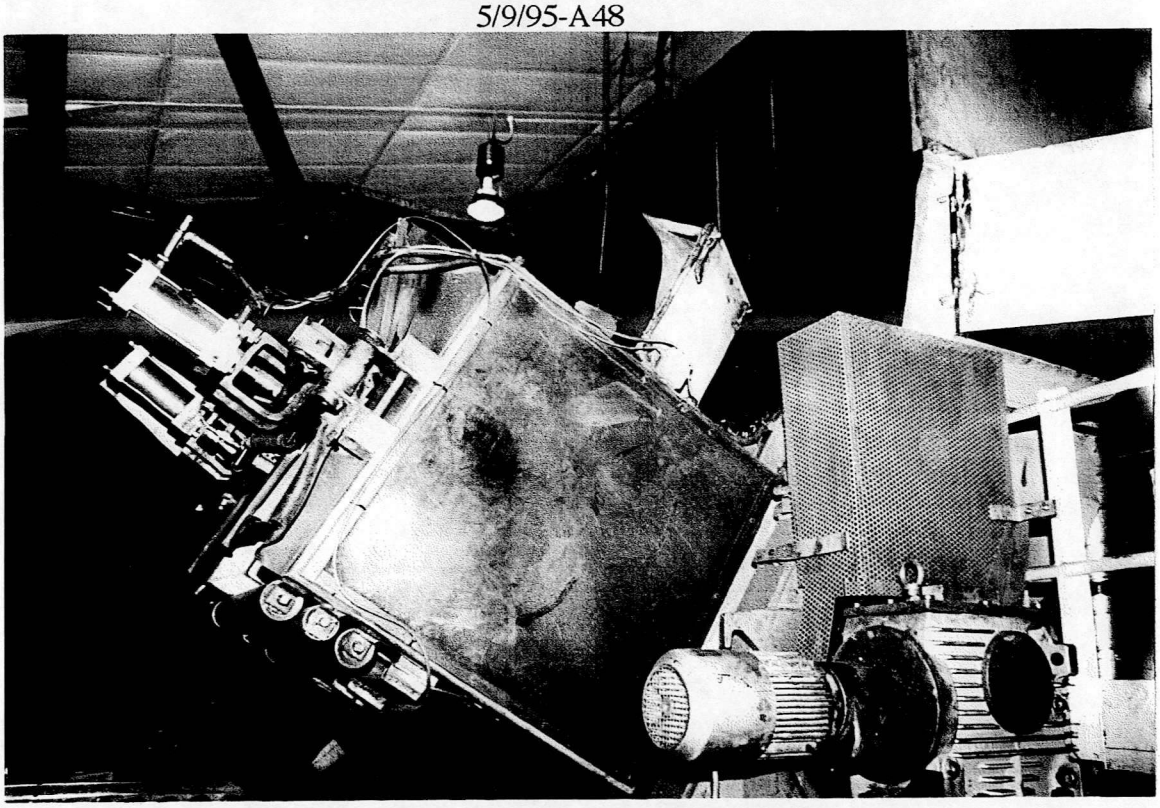
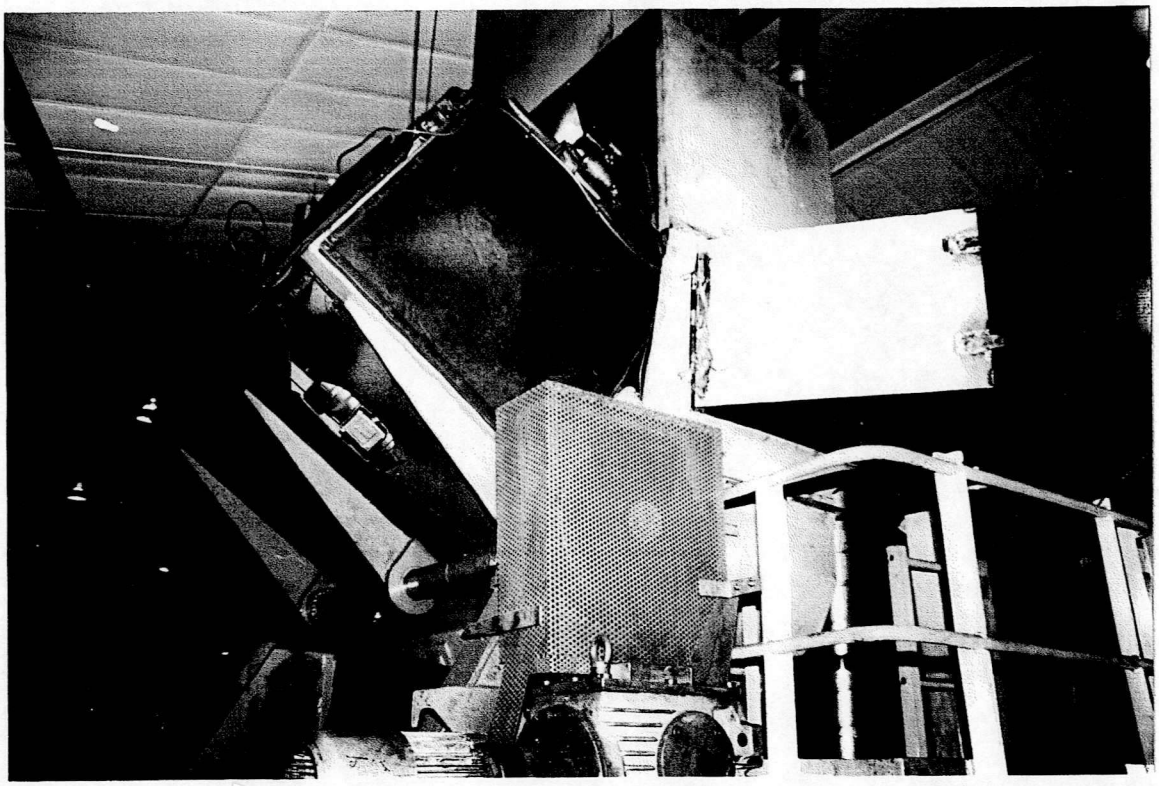


5/9/95-A48

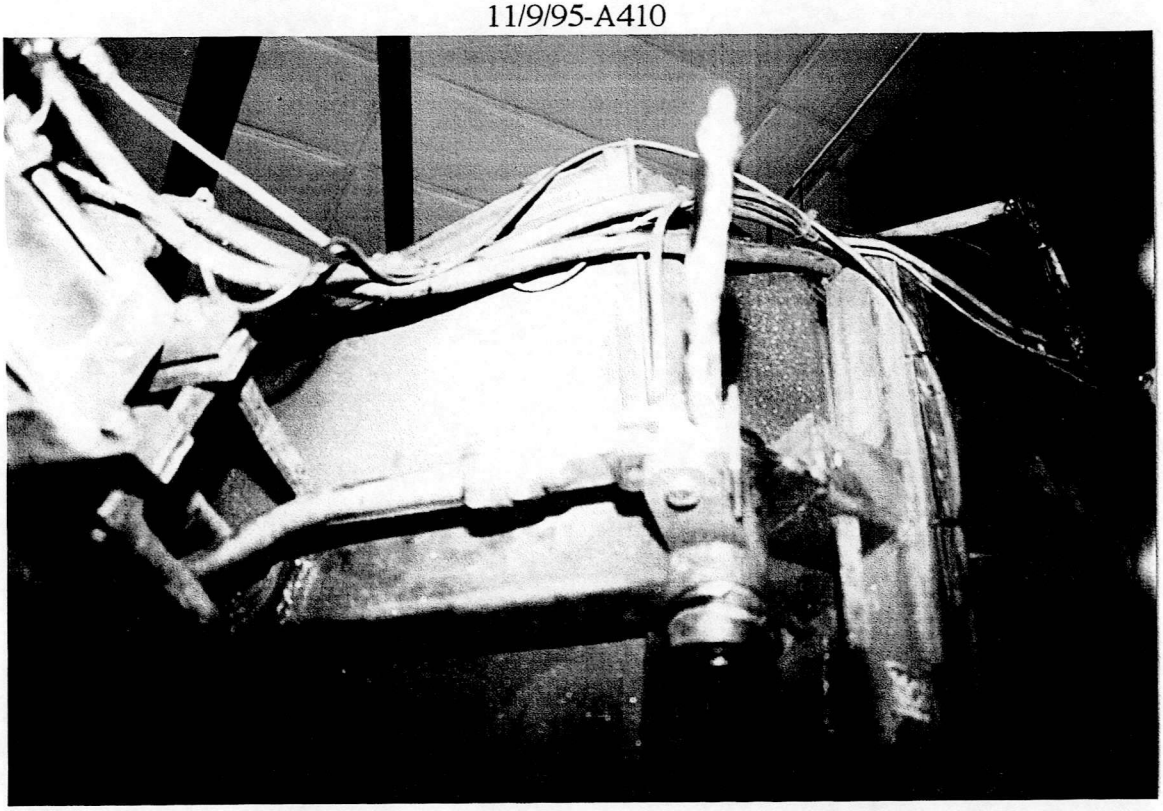


5/9/95-A49

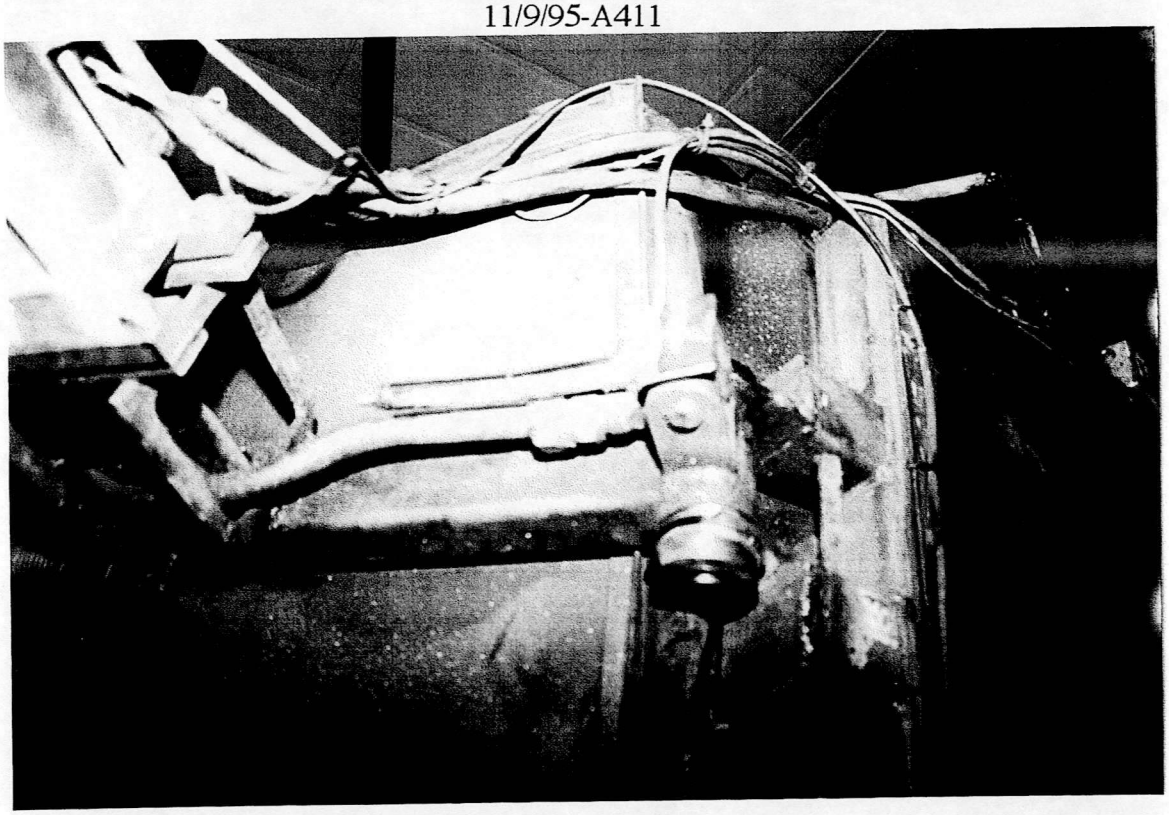


Photographs 11/9/95-A410 and 11/9/95-A411 show the unlatched and latched positions respectively of the right hand safety door manual locking handle.

11/9/95-A410

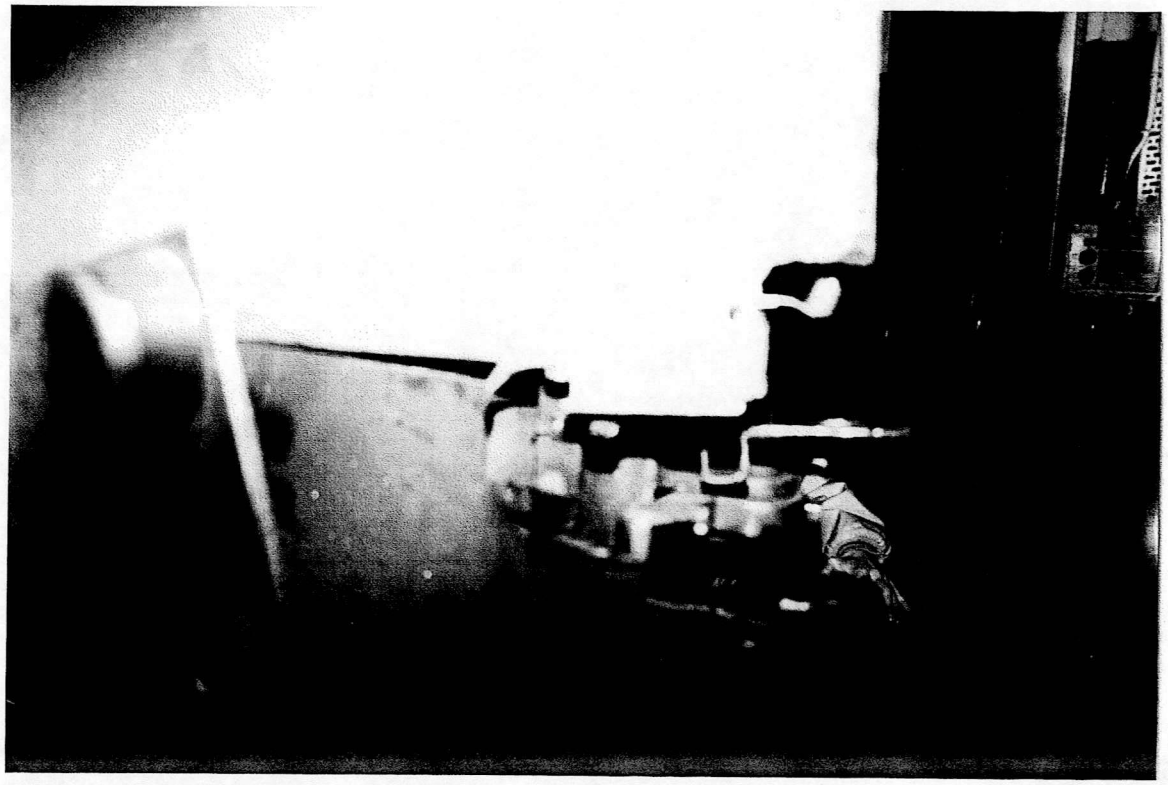


11/9/95-A411



Photograph 11/9/95-A412 This shows the right hand safety door manually operated latch in the open door position. Above the latch is the interlock limit switch. The switch lever is seen to the right of the switch housing.

11/9/95-A412



Photograph 11/9/95-A413 Shows the manually operated door latch in the locked safety door position. The interlock limit switch above the latch has the switch lever pushed counter clockwise to cause the union of the limit switch contacts.

11/9/95-A413